Stages for Teachers," shows a five-stage professional development model based on our analysis, with input from Teaching Matters. Moving teachers from entry through the first two stages could be achieved in half a school year for any one teacher. The prerequisites are adequate access to a computer, courseware to enable the use of technology in the curriculum, and support for the teacher in the classroom. Ideally, the support would come both from experts in the technology and from peer teachers. This implies giving teachers time and encouragement to share experiences with each other.

Experience at schools that have been down this path suggests that the two more advanced stages on the professional development model simply take time—from two to five years of real teaching experience with the technology. In addition, progressing to these stages requires encouragement and incentives for teachers to make the extra effort needed to build their own skills and support other teachers. Thus, a school district that starts now with basic "Adoption" and "Adaptation" training could build a population of appropriately skilled teachers over a six- to seven-year period (assuming two years to move all teachers through the basic training—an aggressive assumption, to be sure).

In the meantime, we believe several actions are appropriate for most schools and districts to consider:

- Give teachers, school librarians, and media specialists access to the technology as soon as possible (school librarians and media specialists are often early adopters and supporters of technology). One of the benefits of the Lab Plus model described above is that it provides a computer for each teacher, school librarian, and media specialist.
- Encourage teacher-led initiatives.
- Create incentives—examine credentialing and pay scales to see if direct incentives can be instituted.
- Beyond basic adoption skills, create training programs that use the technology in support of other skill building objectives (e.g., improving critical thinking, implementing new curricula).
- Examine the 1.8% to 5.7% of the budget that districts currently spend on professional development[45] to make sure it devotes the appropriate emphasis to technology skills.
- Allow teachers, school librarians, and media specialists time to share their experiences and provide some in-class support to one another.
- Set goals for moving the entire population of teachers across the five skill stages.

[45] Consortium for Policy Research in Education, *CPRE Policy Briefs* (June 16, 1995).

Beyond the school and district levels, a number of actions could stimulate professional development of teachers. National leaders should:

- Encourage schools of education to integrate technology into their curricula more fully. However, because only 4% of teachers are newly accredited each year and 25% of these stop teaching within two years, the impact will be slow to be felt—but important nonetheless in setting standards and expectations.
- Encourage schools of education and foundations to fund and monitor experiments to identify effective techniques for the use of technology in K-12 education and for the professional development of teachers and other school professionals.
- Encourage continuing education programs for teachers, school librarians, and media specialists to include courses on effective educational uses of technology.
- Examine the $615 million per year (FY1993) the federal government spends on teacher development in science, math, and technology to make sure that this funding gives proper emphasis to the use of computer and network technology in the classroom.[46]

An aggressive professional development effort involving the support of teachers, administrators, boards of education, states, the federal government, and schools of education will be an essential part of effectively connecting students to the NII.

Ensuring courseware availability

Today, the market for courseware is relatively small, fragmented, expensive to enter, and risky. As a consequence, it is underdeveloped—although this will change as K-12 school demand for courseware grows.

For purposes of this discussion, we have defined courseware as "electronic curricular materials." Courseware includes interactive multimedia software, on-line educational services, teacher's guides, and other materials linked directly to prescribed curriculum. The link to curriculum is critical because teachers have a limited time to cover concepts and facts outlined in the curriculum. Good courseware allows students to work in groups and at their own pace, and to receive quick feedback on their progress.

For production of high-quality courseware to flourish, the courseware market needs to expand and to become more attractive and accessible both to existing and to new providers. Fortunately, as more schools commit to connecting to the information superhighway and find the funding to do so, and as more teachers become knowledgeable and excited about using technology in their classes, demand for courseware will naturally grow. Even so, it might be worthwhile to consider options

[46] Ibid.

for stimulating growth in the courseware industry—for example, speeding up the schools' slow and bureaucratic procurement processes—to make sure that enough good courseware is available to encourage schools and teachers to experiment with technology in the near term.

Small, fragmented market. Just a piece of the overall education market, courseware comes in two basic types: (1) integrated programs that typically support a full-year course, and (2) more tightly focused, modular programs that cover a specific topic (e.g., the Oregon Trail, the writing of the Constitution). The market for both types of courseware totaled about $290 million in 1993-1994.[47]

At $290 million, the courseware market is smaller than other software markets. One particularly relevant comparison is to the home market for educational applications, since developers who have chosen to focus on the education market have told us that the home market is most attractive. LINK Resources estimates the size of the home education software market at $1.4 billion in 1995, and the home "edutainment" market at nearly $500 million.[48] Not only does this substantially exceed the size of the K-12 school market, but it is expected to grow at a more rapid pace over the next several years. The growth in the home market is supported by the increasing penetration of multimedia computers into the home. The number of multimedia computers used for instruction in K-12 schools is projected to grow from about 1.0 million in 1994-1995 to 2.2 million by the 1997-1998 school year,[49] while the number in the home is forecasted to grow from 8.0 million in 1994 to 38.3 million in 1997.[50] If these projections hold, then the number of multimedia computers at home will exceed the number in schools by a factor of 24 to 1 by 1997.

---

[47] This estimate of the size of the courseware market is based on several sources. As mentioned above, there are two types of courseware; the types are called integrated learning systems, or ILS, and modular, unit-based software.

An ILS is a turnkey package that typically supports a full-year course, comes packaged with student management and testing tools, and sometimes includes hardware. Despite their breadth, ILSs are still considered supplemental to textbooks because they typically lack the depth necessary to completely cover a full-year core curriculum. The Software Publisher's Association estimates the software portion of the ILS market at $170 million for 1993-1994. ILSs of the past often had features which caused them to fall out of favor: proprietary hardware, software that did not work with other packages, and a drill-and-practice orientation. ILSs have given way to what one analyst has termed "networked learning systems."

By contrast, modular, unit-based software focuses on a single topic or concept. The size of the market for unit-based software is not tracked separately from the $360 million that schools spend on non-ILS software, which includes edutainment, reference and on-line software and services. Based on interviews and case studies, we estimate that unit-based software accounts for about one-third of this total, or $120 million.

For information about market size, see *K-12 Education Market Report*, supra note 28. For information on market definition, see the Smith, Barney report on Davidson & Associates, August 3, 1993.

[48] *Consumer PC Market Outlook: 1994-1999* (LINK Resources Corporation, June 1995). Tables 6 & 9. The Software Publisher's Association estimates the size of this market for 1994-1995 at $630 million. Edutainment software combines education with entertainment, often in the form of multimedia games. Edutainment products are typically not curriculum-linked and their educational value varies widely.

[49] The 1997-1998 estimate for multimedia-capable computers assumes that K-12 computer shipments continue to grow at 16% per year.

The size of the courseware market is further constrained by the distinction made between core and supplemental materials. By rule, state textbook monies typically go to core materials. Because courseware is normally considered supplemental, this reduces the available pool of dollars for courseware purchase.

In addition to its relatively small size, the courseware market is fragmented into numerous small segments. Programs need to be tailored to different academic subjects and to individual grade and skill levels. While multimedia courseware lends itself to interdisciplinary content that could combine subjects, state curricula are not currently written in a fashion that would lead to approval of most courseware for multiple subject areas.

The combination of a small market, fragmentation, and a relatively more attractive home market has created a chicken-or-the-egg dilemma for courseware developers. If the demand for courseware were larger, developers would produce more and better educational products. On the other hand, the limited spectrum of available products inhibits the development of infrastructure and therefore the growth of demand.

High cost to serve. The developers we interviewed regard the educational market as a difficult place to do business because sales and service are complicated and expensive. Schools' purchasing process is slow and arduous. Approvals are required at many levels and each decision maker has a high need for information.

Twenty-two states select course materials through an "adoption" process that poses three hurdles for courseware developers. First, the interval between selection of materials for a given subject and grade is long—often five years or more. While this may be appropriate for textbooks, for which the process was designed, it is less desirable for software, which changes rapidly. Second, the sales process is expensive and risky, particularly for smaller developers. For example, the textbook choices of Texas and California carry significant weight throughout the country. As a result, vendors spend heavily—with no guarantee of success—to lobby the committees of teachers and other stakeholders who recommend materials in these states. After participating in the adoption process in one of these major states, one developer of highly acclaimed courseware said that it could not afford to do so again for many years. Third, the sales cycle does not necessarily end with adoption. In states that select more than one text, adoption merely signals that the next phase of the sales cycle has begun, this one directed to district- and school-level officials.

In addition to the difficulties with the adoption process, the mechanics of school district purchasing practices are often cumbersome. District agents require purchase orders tailored to their own unique systems. Some want to be billed after the goods have been received;

[50] *Consumer PC Market Outlook: 1994-1999*, supra note 48, Table 4.

others before. Some are restricted from paying until the product has been fully consumed, which is particularly difficult for a product that is part software and part on-line service. Others put off buying until the end of the budget cycle, ordering if they have money left over and requiring delivery within the week. The combined effect of such procurement practices is to raise the costs providers must bear.

The school courseware market is also costly to service due to high training needs. Pioneer providers often face high training costs because teachers are simply not familiar with computers and networks. One developer of a networked application stated that by far the main reason for calls to its help line was that the teacher did not understand how to connect to the network.

Risks of product development. Courseware is relatively expensive to develop and comes with little guarantee of success. The experience of multimedia developers generally is a good illustration of the risks faced by courseware developers specifically. A survey of 912 multimedia software developers conducted by Gistics, a California consulting firm, concluded that 96% were unprofitable.[51]

In addition, multiple platforms further increase the costs of production. The public schools have a mix of Apple Macintoshes, IBM-compatible computers, and older Apple IIe and Commodore machines. While new applications and developers generally aim at the new machines, porting an application developed for the Apple Macintosh Operating System to the Windows operating system can add 10-20% to its cost.

Addressing the courseware challenges. As mentioned above, some of these problems are likely to sort themselves out over time as more schools begin using computers and networks in the classroom, and the market for courseware grows as a result. However, there are steps that could be taken now to stimulate the courseware market in the near term. It is hard to know just how important such steps would be, but they seem to be worth careful consideration.

Perhaps most important, there are a number of ways to address the small size of the courseware market. Clearly stated national goals for deploying technology in the schools, state technology plans, and real appropriations could build confidence among courseware providers that demand will grow and that the growth will be sustained. In addition, changing the rule in many states that prevents textbook money from being spent on courseware would help. Twenty-one of twenty-two adoption states have taken steps in this direction by redefining instructional materials to include electronic content. The next step would be to relax the distinction between core and supplemental materials.

[51] Jim Carlton, "Companies Aim to Dominate Fun Learning," *The Wall Street Journal* (August 2, 1995), p. B1.

Furthermore, the fragmentation of the market into small segments defined by grade and subject is not inevitable. Instead, wider skill-based, cross-disciplinary segments could evolve. Many districts and states are systematically rethinking and updating their curricula. To the extent that the new curricula emphasize flexibility of method and skills over content, this would encourage the formation of these larger, more profitable market segments.

The high cost to serve the K-12 market can also be addressed. Districts can streamline their purchasing practices. Friendlier adoption rules for courseware can be created. And training and support at the school level can be enhanced so that early developers do not have to bear the brunt of training teachers in computer basics and solving their particular hardware problems.

To mitigate the risks faced by early developers, states and districts can enter into partnerships with developers. Agreements might range from providing venture capital, to cooperative development arrangements, and to advance agreements to purchase. For instance, the state of Florida has established a fund to encourage the development of courseware that meets its curriculum needs. In return for providing seed funding, schools within the state receive a discount on packages purchased. Money earned by the state on its investment is returned to the fund, which has just seen its first product complete the cycle through development to sales to dividends. When the Guilford County School District in North Carolina wanted teacher productivity and student performance management software, it scoured the market but could not find the product that met its needs. So it contracted with McGraw-Hill to build the system; McGraw-Hill was pleased by the deal because it reduced the risk of development.

Grants have also been used to stimulate the development of high-quality courseware. Several challenge grants from the National Science Foundation (NSF) have been focused on courseware or the underlying tools to create it.[52] For instance, The Geometer's Sketchpad allows students to test hypotheses in real time on geometric models they create on the computer. Students can explore the model by manipulating objects and observing how the other objects respond. Students' observations can be visual, or they can measure the resulting angles, lengths, and areas using tools built into the program. The Sketchpad grew out of the Geometry Forum, a project at Swarthmore University funded by the NSF.[53]

---

[52] Jerry Michalski, *Release 1.0, Esther Dyson's Monthly Report* (New York: EDVenture Holdings, Inc., May 1995), pp. 2 and 5. The report states: "The U.S. National Science Foundation (NSF) has funded many useful projects along these lines. In fact, almost every project we found intriguing was NSF-backed. It seems strange that NSF is the sole funder of so much activity. There's clearly a greater role possible for software developers and corporations."

[53] Ibid., pp. 5-6.

LEADERSHIP

These challenges—securing funding, ensuring teachers have the skills to integrate applications into the curriculum, and obtaining quality courseware—will set the pace of implementation for many schools. Over time, the market for courseware will develop, teachers will build skills and experience, and determined school districts will find the funds for deployment. As case studies demonstrate, leading-edge schools are already clearing these hurdles, even in relatively poorly funded districts. But facing down competing demands for scarce budget dollars, motivating teachers to make fundamental changes in their approach to teaching, and making creative use of courseware and the Internet, all demand one thing: strong leadership.

And it must be leadership sustained over time. It will take several years, perhaps a decade, for most schools or districts to bring all the necessary elements—infrastructure, funding, professional development, and courseware—into alignment. Through every stage of that deployment period, dedicated leaders will need to provide direction and maintain momentum. This will probably be the single most important factor determining not only the pace of deployment, but also the level of success in capturing the educational benefits of the NII.

Connecting schools to the information superhighway involves a systemic process of change, demanding new styles of teaching and learning and new priorities for funding and resource allocation. To launch and sustain this process, leaders need to provide a compelling vision of success and a sense of urgency, pull together funding from multiple sources, create an environment where teachers can learn and be rewarded for using the technology, and ensure adequate support for both initial deployment and for ongoing operations.

Leadership needs to come at many levels, from both the public and private sectors. There is no "blueprint" for deployment nor single set of national policies that can meet the diverse needs of every school district. For this reason, deployment requires a local, "bottom-up" approach. At the same time, individual schools clearly need top-down help in marshaling the resources to overcome these challenges. In the schools we visited, the district superintendent often has taken the lead role, bringing together community leaders and school boards, teachers and administrators, as well as private industry and government leaders to make change happen.

Local community and school leadership is the most powerful and important source of energy for driving deployment. Without the commitment of teachers, administrators, and parents, little change can happen in the classroom or the school. School boards, superintendents, principals, and other community leaders need to establish a clear vision and agree on concrete goals. They need to redefine teachers' job requirements, reward risk-takers, drum up volunteers to donate services or equipment, secure funding, and guide deployment programs around the snares of the budget and procurement processes.

Some form of public-private partnership lies at the center of many successful community leadership models. In Carrollton, Georgia, for example, active proponents on the school board and senior executives from local businesses drove the deployment process. They helped procure affordable equipment, convinced technical support groups to donate time to run wiring through school facilities, and provided ongoing funding to the school district. At the Dalton School in New York City, parents have supported the effort by endorsing and encouraging the new teaching methods. Columbia University has also provided free connections to its own network and has established a partnership for joint courseware development.

Teachers, too, are critical agents of change. They need to take the initiative to use new teaching techniques and make creative use of the technology. They are the first to encounter the obstacles of inadequate support and courseware, as well as the first to realize the benefits of more engaging learning tools and improved communications. Teachers play a pivotal role in informing, assisting, and coaching their peers, thus building the momentum for change. Innovative teachers often need to be mavericks, giving their own unpaid time to training and finding ways around bureaucratic obstacles.

However, local school and community leadership is necessary but not sufficient to meet the goal of nationwide connection to the NII. Not all school districts have the ability or desire to make deployment a top priority; no individual school or community alone can stimulate the courseware market or legislate new federal funding. **Leadership at the state and national level**—in both the public and private sectors—is also necessary to help speed deployment and ensure that it is equitable.

Many states are developing technology plans that help prioritize uses of state funds and offer suggestions for funding and infrastructure deployment at the school level. Some states, such as North Carolina, have even justified infrastructure build-outs by combining network requirements across several government functions. As discussed above, federal programs currently provide an important source of technology funding. Government agencies also play an important role simply by endorsing the importance of the NII, communicating "best practices," and advocating key initiatives in public forums.

For example, the President's Office of Science and Technology Policy has assisted Gary Beach, the publisher of *Computerworld*, in creating Tech Corps, a national, non-profit organization of technology volunteers dedicated to helping improve K-12 education at the grass roots level. The mission of Tech Corps is to recruit, place, and support volunteers from the technology community (primarily at state and local levels) who advise and assist schools in the introduction and integration of new technologies into the educational system. An early test of the concept began in Massachusetts in March of this year and involved 12 school districts with over 300 volunteers signed up to assist. Based on this success, the program is now expanding to 40 districts in the state.[54]

In addition, public-private partnerships at the state or national level can complement local efforts and government mandates. Purchasing

[54] Interview with Gary Johnson, Executive Director of Tech Corps, September 1995.

cooperatives, for example, are a powerful way to secure discounts or terms that individual school districts could not negotiate on their own. Private foundations or not-for-profit groups, perhaps with government seed money, can spur courseware development and help publicize successful models for deployment. And, as several of the case studies demonstrate, private industry can have an incentive to fund "experiments," such as Bell Atlantic's involvement with the Christopher Columbus Middle School in Union City, New Jersey, in which Bell Atlantic installed computers at the school and the home of all 7th grade students and teachers, along with local and wide area networks to link them. Private industry partners could also be encouraged to play ongoing roles as deployment progresses.

Finally, educational institutions—especially teacher colleges—have an important role to play in revamping their curricula and providing more robust in-service training support to teachers and other school professionals in light of these new technology training needs. They need to advocate changes in teacher certification requirements and to support courseware development efforts by establishing guidelines and quality standards. They can also sponsor conferences and educational forums, bringing together teachers, administrators, courseware developers, and potential funders.

❖ ❖ ❖

There is no magic formula for pulling together the leadership and commitment to change across all these diverse organizations. It is clearly a process, though, that will build on its own momentum. As costs decline, hardware and software evolve, and more teachers become experienced with technology, the perceived risks of deployment will decline. And as more success stories emerge from the growing ranks of innovative schools, documenting the benefits of connection and demonstrating deployment models that work, the enthusiasm and desire to make the change happen will spread from community to community.

APPENDIX A

DETAILS FOR COSTING MODELS FOR CONNECTING SCHOOLS TO THE NII

As discussed in the main body of the report, we constructed several models assuming different levels of infrastructure and timing of deployment to highlight the major cost drivers of technology deployment and the economic breakpoints among deployment options. This appendix is for the reader interested in further detail about cost models.

Costing methodology

For each model, we analyzed the costs associated with six elements of infrastructure: the connection to the school, the connection within the school, hardware, content, professional development, and systems operation. Each of these elements was further broken down into sub-elements. (See Exhibit 15: "Six Elements of Infrastructure.")

We took a three-step approach to estimating the costs for each model. First, we estimated the costs of each of the six infrastructure elements (and sub-elements) for an average school[55] as required by each model. For each element, we estimated the costs of initial deployment as well as ongoing operations and maintenance. Initial deployment costs include the purchase and installation of equipment and first-year operating expenses. Ongoing operations and maintenance costs include usage charges, equipment and content upgrades, and professional development and support. For many elements, we assumed that prices would decline over time. We also made adjustments—based on location and age—to account for major variations in costs from school to school (e.g., the greater cost of deploying computers and local area networks in older schools requiring retrofitting and asbestos removal). Second, we estimated the amount and quality of existing infrastructure for each cost element to determine the true incremental costs of deployment. Third, we scaled the costs up to a national level by multiplying the incremental costs per school by the total number of schools, accounting for the growing student population.[56] For each model, we assumed either a 5 or 10 year deployment period (as noted in Exhibit 4) with the purchase and installation of the equipment evenly spread over that period. All costs are in nominal dollars and assume a 3% inflation rate.

---

[55] Averages for 1994-1995 included: 5.7 schools per district, 533 students per school, 31 teachers per school, 21 classrooms per school, and 25 students per classroom. These averages are derived from figures provided by the National Center for Education Statistics (NCES).

[56] We utilized the following numbers from the National Center for Education Statistics: 84,500 schools, 14,850 districts, 45.0 million enrolled students, 2.6 million teachers, and 1.8 million instructional rooms. The student population is expected to grow by 7% in 2000 over the 1995 base and by 10% in 2005, according to the Department of Education.

Exhibit 15

6 ELEMENTS OF INFRASTRUCTURE

Cost drivers by element

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	• Bandwidth • Medium (i.e., wireline/ wireless) • Installation	• Bandwidth • Medium • Installation	• Computers and associated equipment (servers, printers) • Installation, (e.g., HVAC, electrical, security) • Video and voice equipment for video and voice models	• Courseware • On-line services/ Internet connection • Tools software • Videotapes	• Initial training for -Teachers -Librarians -Media specialists -Administrators	• Designing • Implementing
[illegible]	• Usage fees • Repairs	• Repairs • Modification	• Repairs • Upgrades • Modification	• Replace-ments • Upgrades • Usage fees	• Ongoing training and support	• Operating

Our analysis focused primarily on computer-based infrastructure using networked computers as access devices, though costs were also calculated for dedicated video and for telephones and voice mail. As many industry participants have observed, the distinction among computer, video, and voice platforms will blur as broadband connections become more widely available and as computer technology makes its way into televisions and telephones. Someday, interactive television may rival networked computers as a workable base for connecting schools to the NII. We have focused on computer-based technology because it is widely available today and, therefore, provides a sound basis for cost estimates.

Schools may find they have many connection options, depending on where they are located. These options will include both the medium (for example, wireline options include telephone lines and cable; wireless options include satellite, microwave, and cellular) and the type of service (including bandwidth, features and price) offered. For most schools, we assumed telephone company connections because they are the most widely available two-way connections and, therefore, best lend themselves to pricing estimates. However, because high-bandwidth telephone company connections are not available in all rural areas (or are very expensive), we based some of our models on wireless radio for a portion of schools in rural areas.[57] While satellite, cable, and other wireless connections offer viable and potentially cost-effective alternatives, today only telephone company connections offer full, two-way interactivity to a significant portion of the country.

For purposes of cost analysis, the telephone company connections considered were POTS and T-1 lines. These two offerings represent a limited set of the available services. Individual schools and districts will want to investigate other wide- and broadband services which may be available from the telephone company—including ISDN, frame relay, and LAN interconnection—as well as non-telephone company options. As discussed in an earlier section of this report, alternate services such as ISDN may prove to be more cost-effective.[58] The answer for a given school will depend on its needs, the available options, and the price of those options, all of which vary widely from area to area.

Computer-based infrastructure options

We modeled the technology infrastructure and costs associated with full connectivity in every classroom of every public K-12 school—the Classroom model. We also analyzed three less ambitious models that could be considered as alternative deployment options or as interim steps on the path to classroom connectivity: a Lab model, a Lab Plus model, and a Partial Classroom model. In addition, we considered a Desktop model (one computer per student) but did not focus our attention there, given its relatively high deployment costs.

These computer-based models and their costs are described in several exhibits throughout this report. The key features of each model are explained in Exhibit 3, "Model Features," and the national level costs displayed in Exhibit 4, "Estimated Cost of Deploying and Operating Infrastructure." Exhibit 16, "Model Costs at National Level," shows the breakdown in national costs by element and model. Finally, Exhibit 17, "Different Representations of Model Costs," displays the costs in three ways: national costs, costs per average school, and costs per enrolled student. The costs of the computer-based models are not incremental to one another; this means, for example, that the Classroom model does not include the Lab model.

[57] Fixed wireless solutions have a number of limitations, particularly in urban or suburban environments: a clear line of sight is required, reliability can be low, only data and digitized video can be transmitted, and there is potential for clogging the bandwidth as more and more users seek to utilize wireless communications.

[58] See supra note 26.

Exhibit 16

MODEL COSTS AT NATIONAL LEVEL

Computer-based infrastructure
$ Millions

Element	Lab		Lab Plus		Partial Classroom		Classroom	
	Initial	Ongoing	Initial	Ongoing	Initial	Ongoing	Initial	Ongoing
Connection to school	815	580	1,345	595	1,715	1,030	1,645	920
Connection within school	1,325	200	1,325	200	5,025	410	6,285	570
Hardware	3,540	660	9,835	1,525	13,740	1,130	23,820	1,950
Content	2,135	1,045	4,775	2,335	3,505	1,715	6,605	2,920
Professional development	2,025	1,215	3,510	2,320	3,665	2,435	6,355	5,675
Systems operation	765	245	960	465	1,220	810	2,110	1,890
Total	**$10,605**	**$3,945**	**$21,750**	**$7,440**	**$28,870**	**$7,530**	**$46,820**	**$13,925**

Exhibit 17

DIFFERENT REPRESENTATIONS OF MODEL COSTS

Computer-based infrastructure

Model	National costs $ Billions		Costs per average school $ Thousands		Costs per enrolled student Dollars	
	Initial	Ongoing	Initial	Ongoing	Initial	Ongoing
Lab	11	4	125	45	225	80
Lab Plus	22	7	255	85	460	150
Partial Classroom	29	8	340	90	610	155
Classroom	47	14	555	165	965	275

a. Connection to School

External connection costs include installation, access and usage charges for both the school and the district. We assumed mostly wireline connections (primarily POTS lines for the Lab and Lab Plus models and T-1 lines for the Partial Classroom and Classroom models), although costs for some of the rural schools (27%) were estimated with wireless radio. For example, 50% of the rural schools in the Classroom model were assumed to use POTS lines with wireless radio rather than a T-1 line. We used average current Regional Bell Operating Company (RBOC) tariffs as the basis for cost estimates. Tariffs were assumed to decrease by 3% per year through the deployment period.

As discussed in the body of the report (see Meeting the Funding Challenge), current infrastructure for the connection to the school is quite limited; less than 5% have ISDN or T-1 connections and less than 12% of classrooms have telephones.

b. Connection Within School

Internal connection costs include the materials and labor for installing Ethernet LANs (e.g., cabling and network interface cards) as well as file servers, hubs, and routers. File servers are also included for the district.

Our estimates of the LAN costs varied by the age of the school. The NCES estimates that 65% of schools are more than 35 years old and have not undergone a major retrofit. We assumed that physically wiring these schools would require asbestos removal and other retrofitting (for the Partial Classroom and Classroom models). Given the high cost of such remediation, we assumed that wireless LANs were employed where possible, which we estimated to be half of the schools.[59] The cost of installation for wireless LANs is expected to decrease over the next few years to about $200 per node, directly comparable to wireline solutions. For the other half of older buildings, we assumed $63,500 per school for asbestos removal and additional retrofitting. New schools (5%) were assumed to have adequate wiring already built in. Another 30% of schools are between 5 and 35 years old; we assumed these schools neither had wiring nor required asbestos removal.

We assumed a 10 mbps Ethernet LAN that then shifts over time to a 100 mbps LAN at the same cost. The Lab model includes a server at the school ($3,200) and a server at the district ($10,000); the

[59] 2 mbps wireless LANs have been in existence for some time and proven reliable; 10 mbps LANs (Ethernet equivalent) have recently been introduced and early trials are promising. While their relative price makes wireless LANs attractive wherever remediation would be required, many school buildings have structural barriers that make their use impractical.

Classroom model includes 3 servers ($3,200 each) at the school and 2 at the district ($10,000 each).

Based on our review of survey data, we estimate that 7% of classrooms were connected to an Ethernet or comparable LAN in 1994-1995.[60]

c. Hardware

These costs include multimedia-capable computers, printers, scanners, furniture stations, and security systems. They also include any facility upgrades or retrofitting required in older schools, including electricity and HVAC systems, which we estimated could affect up to 23% and 4% of schools respectively. These costs were estimated to be $240,000 for electricity and $31,800 for HVAC in an average school. Obviously, these costs will vary by age and condition of school, as indicated in the body of the report. A computer replacement cycle of 7 years and 5 to 10 year replacement cycles for the other equipment were incorporated into the ongoing operations and maintenance costs.

We assumed multimedia-capable computer prices of $1,700, a typical price paid today by K-12 schools. We further assumed that this price declines by 4% per year. This relatively small price decline is based on the assumption that schools will continue to purchase multimedia-capable computers that have enhanced functionality as it becomes available and that provide special access features for physically impaired students (e.g., written instructions for the hearing impaired, sound for the sight impaired, and special manipulatives for the physically challenged). This viewpoint is validated by the historical trend and is shared by a number of the major hardware manufacturers, who have plans to add functionality and believe that consumers—including those in the schools—will value the upgraded capabilities for at least the timeframe we consider here.

In addition to each computer, we assumed 2 printers ($535 each) and scanners ($675 each) for the Lab model, and 1 printer and scanner per classroom for the Classroom model. Furniture and security equipment were also included ($355 per computer and $350 per room).

We estimated 14 multimedia-capable computers per school today based on installed base statistics and 1994-1995 shipments. (See Exhibit 18: "Instructional Multimedia Computers Per School.") However, these computers are distributed unevenly across schools. We have taken this uneven distribution into account in the Lab model; the adjustment represents approximately a 10% increase in hardware costs. In addition, we assumed an installed base of 1 printer and 3 security/furniture stations per school.

[60] For further discussion on this point, see supra note 28.

Exhibit 18

INSTRUCTIONAL MULTIMEDIA COMPUTERS PER SCHOOL

Thousands

			Instructional	
	Total	Administrative	Non-Multimedia Computer	Multimedia Computer
1993-94 installed base	5,500	1,265	3,705	530
				[redacted]
1994-95 shipments	1,000	230	75	695
				[redacted]

Source: QED; Apple; Paul Kagan Associates; CCA Consulting; McKinsey analysis

d. Content

Content costs include prepackaged software and access and usage charges for on-line services. Software upgrades were assumed to be annual or biannual depending on the particular package or service. Ongoing assumptions for software included expenditures for bilingual capability where applicable. While we made specific assumptions about prepackaged software versus services, our belief is that these costs are interchangeable. In total, the expenditure on software for the Lab model in the year 2000 is 30% higher than expenditures on all electronic media today; for the Classroom model, the expenditure in 2005 is 230% higher than today. Future costs were assumed to decrease at 3% per year.

According to NCES data, approximately 35% of schools currently have access to the Internet or commercial on-line services. Once again, however, most of these connections are available only in the school library and/or media center.

e. Professional Development

These costs include substitute teachers (at $100 per day) to cover times when teachers are out for training, as well as support resources—$^{1}/_{4}$ full-time equivalent (FTE) in the Lab model and 1$^{1}/_{2}$ FTE in the Classroom model—shared across the district to help teachers integrate the technology into the curriculum. Costs for the training courses themselves were also included.

In concert with Teaching Matters, we estimated that 50% of the teachers are at the entry level, 25% at adoption, 20% at adaptation, and 5% at appropriation per the stages shown in Exhibit 14: "Teacher Skill Stages." In the Lab model, trainees (teachers, school administrators, librarians, and selected district personnel) receive sufficient instruction to attain basic adoption level (30 hours); in the Classroom model, 80% of teachers are trained to the adaptation level and 20% are trained to a higher level.

f. Systems Operation

Systems operation costs include resources shared across the district dedicated to designing and operating the systems. The initial deployment costs for the Lab and Classroom models are $5,300 for design charges and 1/4 FTE and 1/2 FTE respectively. These same FTEs are assumed on an ongoing basis.

Video Infrastructure

Two video infrastructure models were costed: a business-quality video facility and a low-end professional-quality video facility. These models were costed as incremental to the Classroom (or Partial Classroom) model.

Both models assumed a single video room with a monitor, three cameras, soundproofing material, and microphones. The business-quality facility has a T-1 connection and assumes equipment at a price of approximately $19,000. For 50% of rural schools, we assumed wireless radio with a POTS backchannel (instead of a T-1 connection). The low-end professional-quality facility has a T-3 connection and assumes equipment at a price of approximately $46,000. Telecom charges were based on average RBOC tariffs.

In addition, initial professional development costs were assumed to be $1,775 per school for teachers, and initial and ongoing system operation costs were assumed to be $9,300 and $11,240, respectively, representing a part-time facilitator/system administrator.

Voice Infrastructure

Costs were also estimated for providing voice mail to all schools and for placing telephones in all classrooms. The voice mail costs are independent of the computer-based models, but the classroom telephones assume that classroom wiring is already in place (i.e., the Partial Classroom or Classroom models).

The voice mail option assumes a dedicated voice mail server for each school ($1,500) and the use of one POTS line. Costs for initial training were assumed to be $1,000. No additional allowance was

Exhibit 19

VIDEO AND VOICE INFRASTRUCTURE OPTIONS*

National Costs

$ Millions

	Business video		Lower-end professional video		Voicemail and telephones	
Element	**Initial**	**Ongoing**	**Initial**	**Ongoing**	**Initial**	**Ongoing**
Connection to school	150	0	5,320	2,865	280	245
Connection within school	0	0	0	0	0	0
Hardware	1,155	95	2,785	230	435	25
Content	0	0	0	0	0	0
Professional development	150	0	150	0	0	0
Systems operation	785	950	785	950	85	0
Total	**$2,240**	**$1,045**	**$9,040**	**$4,045**	**$800**	**$270**

* Incremental costs above computer-based infrastructure; thus; some elements are negligible

made for ongoing support; it was assumed this would be handled by dedicated computer support staff.

For the classroom telephone option, 1 telephone per classroom was assumed with 4 telephones per outside line; schools install multiple new POTS lines connected to a concentrator. Once again, costs for professional development and ongoing operations support were assumed to be minimal.

The national costs for video and voice infrastructure, by the six elements, are displayed in Exhibit 19.

MODELS AND COST ESTIMATES FROM OTHER STUDIES

In addition to this report. we are aware of three studies that estimate the national costs of connecting all public K-12 schools to the NII. We thought it might be helpful for the reader if we briefly summarized the approaches taken by each study and the resulting estimates. The natural tendency would be to directly compare estimates among the studies; however, since each study models different infrastructures, this comparison is difficult. Accordingly, it seems more useful to review the major similarities and differences in approaches and conclusions among each of the studies. We should also note that each study has informed our thinking, and we have appreciated the opportunity to exchange ideas with the authors of the first two studies (the last one is yet to be published). The three studies are:

- *Architecture and Costs of Connecting Schools to the NII* (Lee McKnight and Russell Rothstein, MIT Research Program on Communications Policy, 1995; updating and revising Rothstein, U.S. Department of Education White Paper, 1994)
- *Schools in Cyberspace: The Cost of Providing Broadband Services to Public Schools* (Telecommunications Industries Analysis Project (TIAP), ~~July 1995~~)
- *Technology in America's Public Schools: Getting It In, Getting It Paid For, and Getting It Used* (not yet published, Milken Institute for Job & Capital Formation, 1995).

MIT/Department of Education

The MIT/Department of Education studies informed our approach early on. The 1995 update (referred to simply as MIT from here on) discusses five models of connectivity which include increasing levels of functionality and expense across all elements of infrastructure.

- MIT's Model 3 ($4 to $10 billion in one-time costs, $1 to $3 billion in ongoing costs) contains many of the same cost elements as our Lab model ($11 billion and $4 billion), though Model 3 distributes the computers among classrooms
- Model 4 ($9 to $22 billion one-time, $2 to $5 billion ongoing) is similar in concept to our Classroom model, though by providing for fewer computers it comes closer in cost to the Partial Classroom model ($29 billion and $8 billion).

Several factors account for the differences between the estimate from the MIT study and this study. First, the costs for each model in the MIT work are presented as ranges, while we have estimated a weighted average cost by making assumptions about the distribution of individual costs across schools. For example, within each model the MIT work assumes a single type of connection to the school for all schools, while our approach differentiates between rural and non-rural schools. Second, while the models describe similar levels of infrastructure, they are not identical. Third, the MIT models assume that the current costs for deployment and operation/maintenance remain constant over time, while we have adjusted for declining prices in certain items. Fourth, we have included some initial costs that the MIT researchers have excluded by design—for example, certain software (specifically, packaged applications), furniture stations, printers, and security devices. Finally, we have made different ongoing cost assumptions. Relative to this study, the MIT report assumes less training and support, hardware replacement cycles that are (implicitly) over twice as long, and no packaged software or upgrades.

TIAP

The TIAP study is also similar in approach in that it estimates the costs for three deployment models from the ground up. The TIAP models, for which annual costs are estimated based on five- and twenty-year deployment cycles, are as follows:

- "Teacher-only" ($4 to $6 billion per year over 5 years, and $0.2 to $1.2 billion per year over 20 years)
- "Team of students" ($10 to $12 billion per year over 5 years, and $0.2 to $2.9 billion per year over 20 years)
- "Universal access" ($27 to $31 billion per year over 5 years, and $1 to $9 billion per year over 20 years).

While the TIAP study assumes broadband deployment in all models, it nevertheless concludes that the costs of connection to the school are low relative to the other elements of hard and soft infrastructure (except under a scenario of accelerated broadband deployment coupled with teacher-only access).

In addition to assuming broadband in all models, the TIAP study is different from this report in other respects. First, it does not reduce deployment costs by the currently installed base of computers within the schools. Second, it does not include telecommunications usage charges to the schools; instead, it includes the costs to the Local Exchange Carriers (LECs) of providing broadband service. The TIAP study makes this distinction in order to separate the issues of cost and price for several reasons. First, there is no known tariff for broadband access to schools or any suitable analogous tariffed service. Second, it was conjectured that the costs to provide broadband access to schools might be recovered in ways other than the usual tariffing process.

Milken

The Milken study takes an entirely different approach. Researchers at the Institute surveyed the state education superintendents as to what it would cost to complete their K-12 technology plans. Based on the 40 states that responded to the survey, the Institute projected a cost of $31 billion to "fully implement [each state's] vision for technology." While details of the underlying state technology plans were not available at the time of writing, it appears that the state plans are, on average, less ambitious than the Classroom model outlined in this report. Further, the Milken study seems to have focused on the costs to deploy the infrastructure, not to operate and maintain it.

APPENDIX C

BREAKDOWN OF CURRENT TECHNOLOGY SPENDING IN PUBLIC K-12 SCHOOLS

We have estimated that 1.3% of the public K-12 educational budget, or $3.3 billion in 1994-1995, is currently spent on technology. This figure includes estimates for each of the six infrastructure elements described in Appendix A. A bottom-up approach to estimating this number is described in Exhibit 20: "Estimating Spending on Public K-12 Instructional Technology."

To cross-check the reasonableness of this estimate, we placed it up against overall spending figures from the Software Publishers Association, Peter Li Education Group, and Anne Wujcik & Associates. In order to make such a comparison, we adjusted their figures to ensure that we were comparing like items. For instance, the Software Publishers Association estimated hardware and software purchases alone at $2.4 billion for 1993-1994[61]—or $2.8 billion for 1994-1995 assuming a 16.5% growth rate. Excluding administrative use, and including expenditures for telecom charges, retrofitting, professional development and systems operation, leads to an estimate of $3.4 billion, or 1.4% of the education budget. The Peter Li Education Group and Anne Wujcik & Associates estimated $2.4 billion in 1994-1995 for instructional technology.[62] Adjusting this figure for retrofitting, professional development, and systems operation leads to $3.2 billion, or 1.3% of the public K-12 budget.

---

[61] *K-12 Education Market Report*, supra note 28, p. 61.
[62] Peter Li Education Group and Anne Wujcik & Associates, reprinted in ibid., p. 62.

Exhibit 20

ESTIMATED SPENDING ON PUBLIC K-12 INSTRUCTIONAL TECHNOLOGY

$ Billions

Element of Infrastructure	Spending	Comment/rationale
Connection to school	$0.2	• Applied lab model estimate, since current deployment pattern and spending on other elements of infrastructure consistent with that model • Internet and other on-line usage low; distance learning relatively more expensive but not in wide use • This figure should grow faster than overall total over next several years
Connection within school	0.5	• Total hardware spending (LANs and computers) estimated at $1.8 billion (SPA figures adjusted to account for growth and exclude administrative spending) • Add retrofitting and cabling costs, at 15-35% of LAN total—assume low side today
Hardware	1.4	Computers • QED, Apple, Paul Kagan: estimated 600,000 computers to be shipped in 1994-95 for instructional use • SPA/CCA Consulting: estimated 470,000 computers shipped in 1993-94 for instructional use (550,000 with 16% growth) • At $1,700/computer=$0.8 billion to $1.0 billion • Peter Li/Anne Wucjik & Associates estimated at $0.8 billion Retrofitting, security, other hardware (including video), furniture: estimated at 40% of hardware total
Content	0.8	• Software: $0.5 billion (SPA) • Other content conservatively estimated at $0.3 billion (Peter Li & Anne Wucjik, SPA)
Professional development	0.3	Estimated at 10% of total based on case studies, interviews
Systems operation	0.1	Estimated at 5% of total based on case studies, interviews
Total	**$3.3**	**Equals 1.3% of 1994-95 public K-12 spending**

GLOSSARY

Analog: Representing changing values by a variable physical property such as voltage in a circuit or liquid level in a thermometer. As contrasted to *digital* (see below), which represents changing values by binary digits, or *bits*.

Bandwidth: The speed or capacity of a network connection. The more bandwidth a particular medium has, the faster data can be transmitted across it.

Bit: Binary digit, the basic unit of information carried by *digital* systems, transmitted as a single on or off pulse. Bits are grouped together in different sequences to represent all kinds of information—numbers, words, sounds, images, etc.

Broadband: Network connection that can carry multiple signals at once, each on separate channels. Broadband networks can transmit a lot of data, including voice and video, rapidly over long distances.

CD-ROM: Compact Disk-Read Only Memory; a format for storing large amounts of data (e.g., an encyclopedia, complete with photographs and drawings) on compact disks.

Digital: Representing data as discrete *bits*, as opposed to *analog* (see above). For example, CD players are digital: they convert and store sound as bits. Record players, by contrast, are analog devices.

Distance learning: Using video technology to allow students in one location to participate in a class being broadcast from another location.

E-mail: Electronic mail—messages transmitted electronically between computers.

Ethernet: A protocol and set of cabling specifications for local area networks. Ethernet has a transfer rate of 10 megabits per second.

Hard disk: A computer storage medium that is a fixed part of the computer's hardware (specifically, the data storage part of the computer's hard disk drive). As contrasted to *floppy disk*, a portable computer storage medium that can be inserted into or removed from various computers easily and quickly.

Interactive: Referring to programs or applications that respond directly to the user, taking instructions and giving feedback.

Internet: An international computer network that links over ten thousand individual networks and supports millions of users.

ISDN: Integrated Services Digital Network, a worldwide digital transmission network and format that can carry both data and voice over a single cable at speeds of 56 kbps and higher.